Reverberation Studies in ASIAEX

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Grant Number: N00014-01-1-0217

LONG-TERM GOALS

The general goal of this research is to advance the knowledge base for low frequency reverberation in shallow water environments. This requires an understanding of the basic physics of the propagation and scattering of acoustic waves in such environments, described in a self-consistent manner.

OBJECTIVES

This report summarizes the modeling of acoustic data collected during the East China Sea (ECS) component of the Asian Sea International Acoustics Experiment (ASIAEX), and the theoretical development of a scattering model to explain low frequency reverberation.

APPROACH

The methodology used in this research is as follows. By analyzing multiple-frequency transmission data in the form of received time series on a vertical line array (VLA), one can in principle estimate the essential geoacoustic properties of the seabed. The approach is to take advantage of the acoustic field's sensitivity to the effects of the interaction of sound with the seabed to estimate its geoacoustic properties. Assuming that one is successful in obtaining the average seabed geoacoustic structure from the forward transmission data, this information is then used to compute the Green's function propagator in the absence of scattering. This Green's function, along with a model of the scattering potential, are essential elements in producing a physical picture of the reverberation caused by scattering on and within the seabed. A self-consistent analysis refers to this unified description of both forward and backward scattering. As a first-order reverberation analysis, it is useful to compare integrated bottom scattering strengths derived from the use of the propagation Green's function and the monostatic reverberation data measured during ASIAEX with scattering strengths obtained from other experiments in the same general location. A more microscopic approach is to then model the reverberation by solving the basic integral scattering equations where the scattering results from small fluctuations of sound speed and density within the body of the seabed and rough interfaces. The basis of the idea of first solving the forward propagation problem before trying to understand the basic physics associated with back scattering is the observation that geoacoustic and scattering parameters are strongly coupled, making it very difficult to extract information on the scattering potential from reverberation data alone.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Reverberation Studies in ASIAEX**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Research Laboratories,The University of Texas at Austin,,P. O. Box 8029,,Austin,,TX, 78758**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

WORK COMPLETED

PROPAGATION ANALYSIS: Time series data obtained during the ECS component of ASIAEX have been analyzed for the information they contain on the characteristics of the seabed; this data was collected by P. Dahl and J. Miller on the VLA belonging to the Applied Physics Laboratory, University of Washington (APL-UW/URI), using sources deployed by researchers from the Institute of Ocean Acoustics (IOA), Beijing, China. A broadband normal mode approach was used to model the measured time series in the 10–500-Hz band. The complex multipath arrival pattern, as a function of source-receiver range and source depth, allows one to infer certain characteristics of the seabed.

Figure 1 shows an example comparison of modeled and measured time series at a source-receiver range of about 17 km. The comparison is made in sequential order for the time series on the VLA. Table 1 shows the geoacoustic profile, used in conjunction with a measured sound speed profile and water depth that was input into a broadband normal mode algorithm to generate the modeled time series in the 50–350-Hz band. The computed frequency response was multiplied by the source spectrum generated by a Wakely model for a 38-gm TNT charge detonated at a depth of 55 m. A group of arrivals shown in Fig. 1 are very sensitive to the surface sound speed of the sediment. On the basis of sensitivity studies, the surface sound speed of the sediment was estimated to be about 1640 m/s. The attenuation and the frequency exponent were adjusted within reported bounds to give a modeled time spread that agreed with the measured data over a 20-km range interval (about 200 water depths). Figure 2 compares the measured and modeled magnitude of the received spectra for a single hydrophone for the 17-km event. One observes that all the complicated effects of multipathing are superimposed on the envelope of the source amplitude. Figure 3 shows a comparison of modeled transmission loss (TL) that employs the same geoacoustic profile presented in Table 1 and measured TL collected at a nearby location during a different experiment. The data are in the form of octave-averaged TL, and in order to simulate the effects of octave averaging, the modeled TL employs an incoherent modal sum that eliminates interference patterns. The level of agreement between measured and modeled time series and TL is an indication that the geoacoustic profile may be accurate enough to be employed to construct the two-way Green's function in a scattering computation.

The geoacoustic profile obtained thus far for the ECS component of ASIAEX is consistent with that reported by Collins, Sutton, and Ewing.[1] They reported on measured cores and shear wave experiments at several sites around the ECS ASIAEX location. The surface sediment may be viewed as a medium-grained sand with a low effective attenuation. According to Collins et al., the first sediment layer overlies a harder layer of sand and gravel. Thus far the analyses have not yielded a sediment thickness or the properties of the second sediment layer with any degree of certainty.

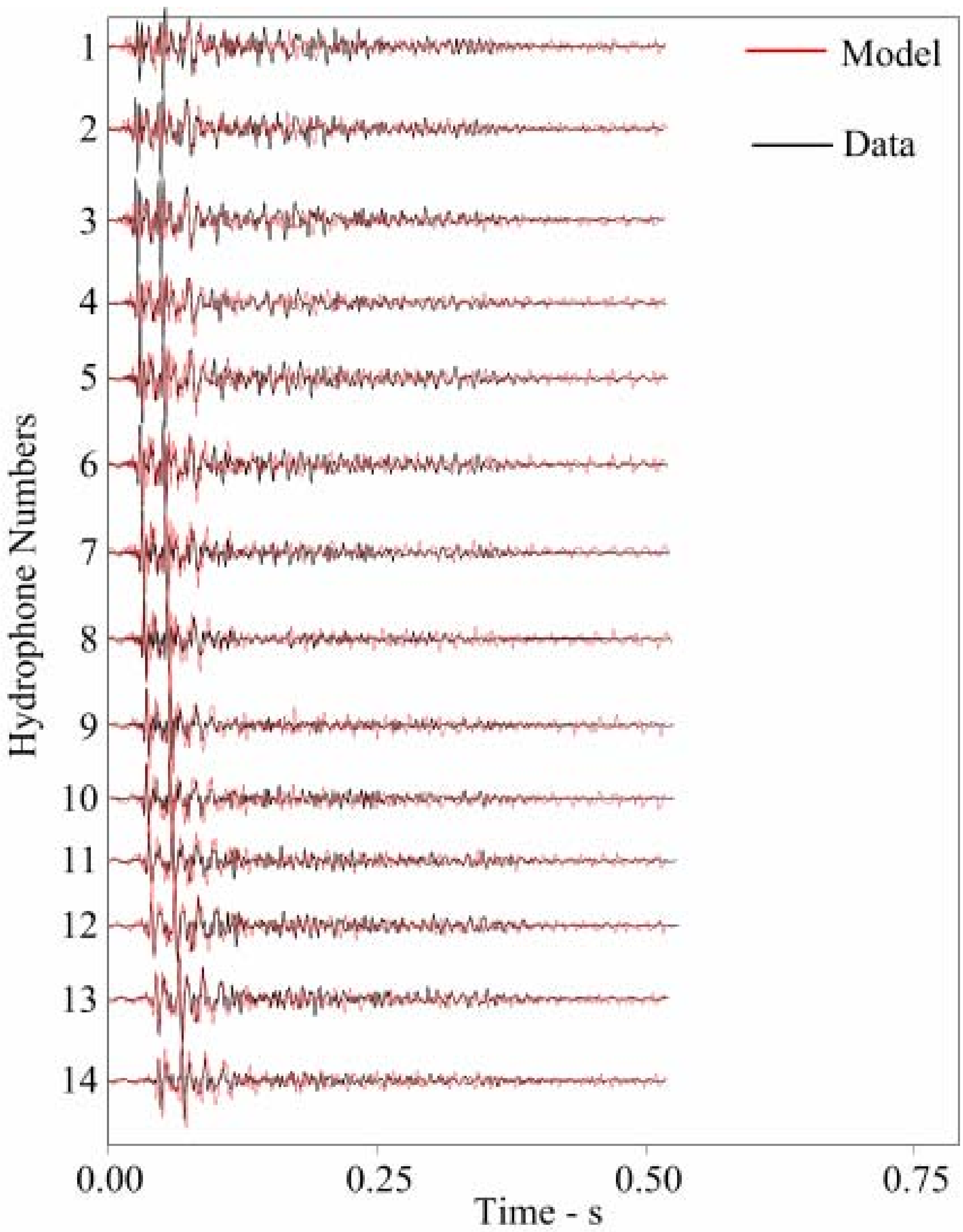

Figure 1: Comparison of modeled and measured time series data taken in East China Sea near HEP site. 50–350 Hz. 38-gm shot. Range,
16.9 km; source depth, 55 m. (Data collected by P. Dahl and J. Miller from APL-UW/URI vertical line array during ASIAEX.)

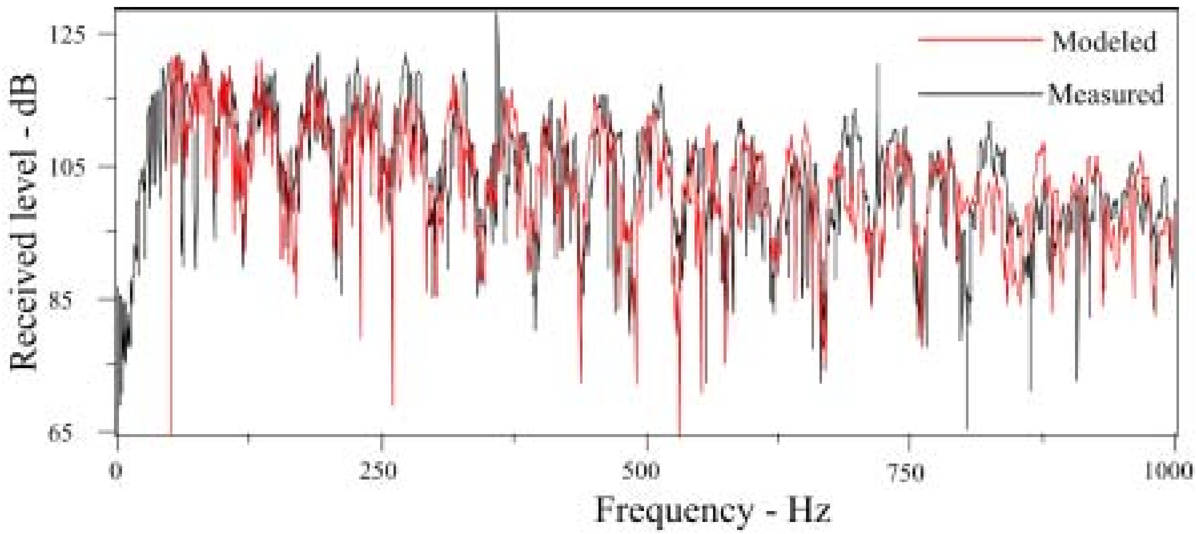

Figure 2: Comparison of modeled and measured magnitude of spectrum for a single hydrophone. Data taken during ECS component of ASIAEX experiment. Source receiver range, 16.94 km; source depth, 55 m.

CURRENT RESEARCH

SCATTERING ANALYSIS: In March 2002, reverberation data, measured by Renhe Zhang, Zhaohui Peng, and Jixun Zhou (IOA) on the RV Shi-Yan III, were made available to Applied Research Laboratories, The University of Texas at Austin (ARL:UT), for analysis. Using the geoacoustic profile extracted from the time series recorded on the APL-UW/URI VLA, we have begun analysis of the monostatic reverberation data. For a preliminary characterization of the data, we have computed range-dependent and average scattering strengths of the seabed using the approach previously reported by Urick.[2]

In addition to the empirical analysis described above, we have developed a theoretical model of reverberation caused by scattering from inhomogeneities in density and sound speed throughout the volume of the seabed. This model is based on a first-order perturbative treatment of the Helmholtz equation, wherein the inhomogeneities are described by a power spectrum following a power law distribution. We have developed a computer algorithm using a broadband normal mode approach (the same as that used in the analysis of the forward data) to implement the theoretical scattering model to simulate reverberant time series. Tests of this algorithm are nearly complete, having produced simulated time series based on the geoacoustic profile mentioned above, and on various power spectra.

SUMMARY: A brief discussion has been presented about research methods and results concerning propagation and scattering in a shallow water environment. Additional results of the forward propagation and the reverberation analysis will be presented in the next ASIAEX meeting in Chengdu, China, and at the December 2002 Acoustical Society of America meeting.

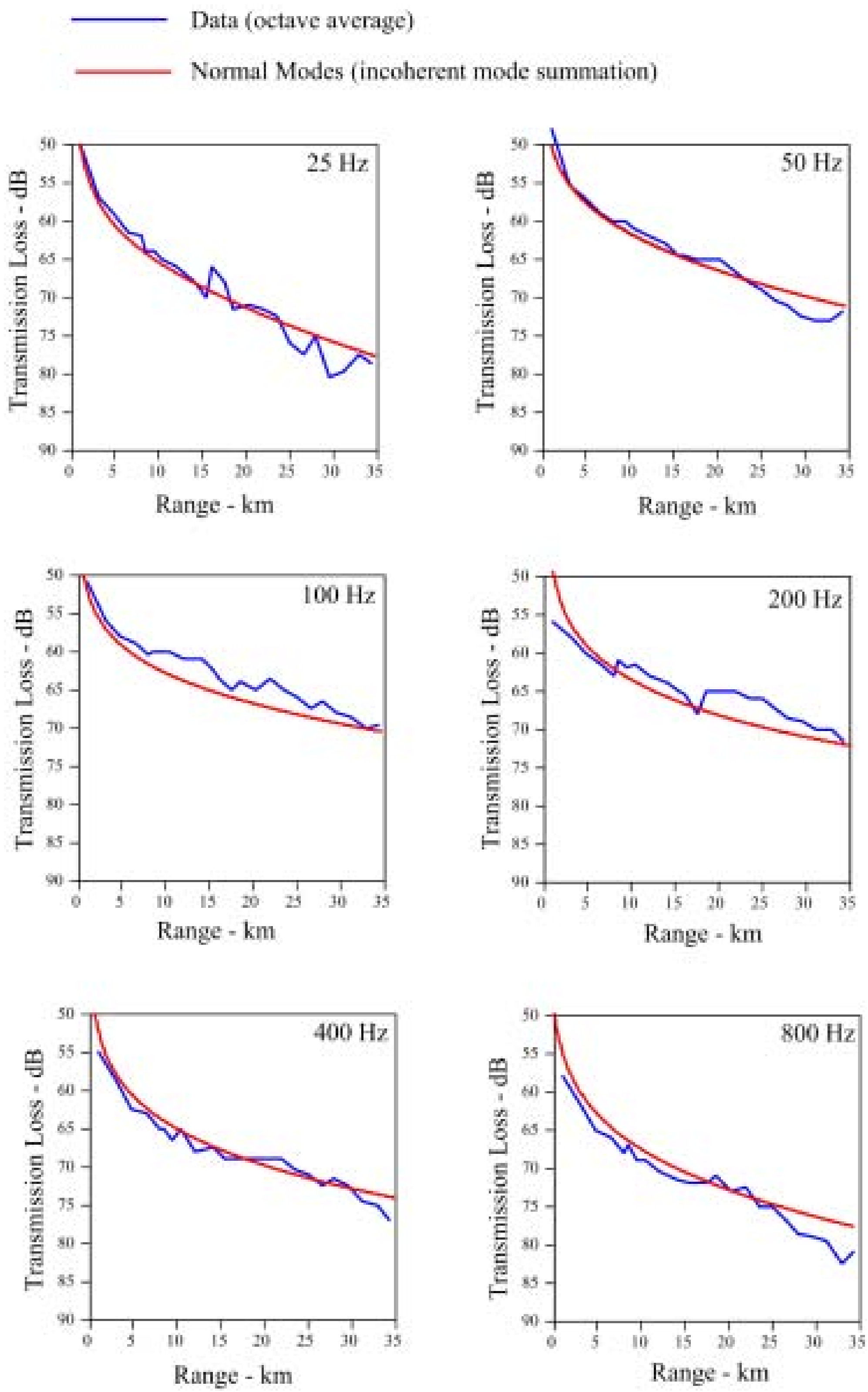

Figure 3: Data-model comparisons of TL from East China Sea location that is approximately collocated with ASIAEX ECS site. Model calculations made using geoacoustic profile in Table 1.

Table 1: Geoacoustic model for area in East China Sea obtained from analysis and inversion of TL and time series data.

Depth - m	Compressional Speed - m/s	Density - g/cc	Attenuation db/m-kHz	Frequency Exponent	
0.0	1640.0	1.76	0.45	1.8	Sand
7.62	1664.86	1.76	0.45	1.8	
7.62	1839.82	1.9	0.268	1.0	Sand-Gravel
95.48	1918.08	1.9	0.268	1.0	
95.48	3000.0	2.5	0.02	1.0	Basement

REFERENCES

1. J. A. Collins, G. H. Sutton, and J. I. Ewing. " Shear-wave velocity structure of shallow-water sediments in the East China Sea," J. Acoust. Soc. Am. **100**, 3646-3654 (1996).

2. R. J. Urick, " Reverberation-derived scattering strength of the shallow sea bed, " J. Acoust. Soc. Am. **48**, 392-397 (1970).